Researchers devise more efficient materials for solar fuel cells

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University of Texas at Arlington chemists have developed new high-performing materials for cells that harness sunlight to split carbon dioxide and water into useable fuels like methanol and hydrogen gas. These "green fuels" can be used to power cars, home appliances or even to store energy in batteries.

"Technologies that simultaneously permit us to remove greenhouse gases like carbon dioxide while harnessing and storing the energy of sunlight as fuel are at the forefront of current research," said Krishnan Rajeshwar, UTA distinguished professor of chemistry and biochemistry and co-founder of the University's Center of Renewable Energy, Science and Technology.

"Our new material could improve the safety, efficiency and cost-effectiveness of solar fuel generation, which is not yet economically viable," he added.

The new hybrid platform uses ultra-long carbon nanotube networks with a homogeneous coating of copper oxide nanocrystals. It demonstrates both the high electrical conductivity of carbon nanotubes and the photocathode qualities of copper oxide, efficiently converting light into the photocurrents needed for the photoelectrochemical reduction process.

Morteza Khaledi, dean of the UTA College of Science, said Rajeshwar's work is representative of the University's commitment to addressing

critical issues with global environmental impact under the Strategic Plan 2020.

"Dr. Rajeshwar's ongoing, global leadership in research focused on solar fuel generation forms part of UTA's increasing focus on renewable and sustainable energy," Khaledi said. "Creating inexpensive ways to generate fuel from an unwanted gas like carbon dioxide would be an enormous step forward for us all."

For the solar fuel cells project, Rajeshwar worked with Csaba Janáky, an assistant chemistry professor at the University of Szeged in Hungary and Janáky's master's student Egon Kecsenovity. Janaky served as a UTA Marie Curie Fellow from 2011 to 2013.

The findings are the subject of a Feb. 15 minireview, "Electrodeposition of Inorganic Oxide/Nanocarbon Composites: Opportunities and Challenges," published in *ChemElectroChem Europe* and a companion article in the *Journal of Materials Chemistry A* on "Decoration of ultra long carbon nanotubes with Cu2O nanocrystals: a hybrid platform for photoelectrochemical CO2 reduction."

"The performance of our hybrid has proved far superior to the properties of the individual materials," Rajeshwar said. "These new hybrid films demonstrate five-fold higher electrical conductivity compared to their copper oxide counterparts, and generate a three-fold increase in the photocurrents needed for the reduction process."

The new material also demonstrates much greater stability during long-term photoelectrolysis than pure copper oxide, which corrodes over time, forming metallic copper.

The research involved developing a multi-step electrodeposition process to ensure that a homogeneous coating of copper oxide nanoparticles

were deposited on the carbon nanotube networks. By varying the thickness of the carbon nanotube film and the amount of electrodeposited copper oxide, the researchers were able to optimize the efficiency of this new hybrid material.

Rajeshwar also is working with Brian Dennis, a UTA associate professor of mechanical and aerospace engineering, and Norma Tacconi, a research associate professor of chemistry and biochemistry, on a project with NASA to develop improved methods for oxygen recovery and reuse aboard human spacecraft.

The team is designing, building and demonstrating a "microfluidic electrochemical reactor" to recover oxygen from carbon dioxide extracted from cabin air. The prototype will be built over the next months at the Center for Renewable Energy Science and Technology at UTA.

Rajeshwar joined the College of Science in 1983, is a charter member of the UTA Academy of Distinguished Scholars and senior vice president of The Electrochemical Society, an organization representing the nation's premier researchers who are dedicated the advancing solid state, electrochemical science and technology.

He is an expert in photoelectrochemistry, nanocomposites, electrochemistry and conducting polymers, and has received numerous awards, including the Wilfred T. Doherty Award from the American Chemical Society and the Energy Technology Division Research Award of the Electrochemical Society.

Rajeshwar earned his Ph.D. in chemistry from the Indian Institute of Science in Bangalore, India, and completed his post-doctoral training in Colorado State University.

More information: Csaba Janáky et al. Cover Picture: Electrodeposition of Inorganic Oxide/Nanocarbon Composites: Opportunities and Challenges (ChemElectroChem 2/2016), *ChemElectroChem* (2016). DOI: 10.1002/celc.201600014

E. Kecsenovity et al. Decoration of ultra-long carbon nanotubes with Cu O nanocrystals: a hybrid platform for enhanced photoelectrochemical CO reduction , *J. Mater. Chem. A* (2016). DOI: 10.1039/C5TA10457B

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